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Combining Teaching Experiments and Professional Learning: Conflicts between Research and Teacher Outcomes

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This paper examines the conflict in interest between teaching experiments and professional learning when they are combined in a research project. The study reported in this paper is the fourth year of a five year longitudinal study on the introduction of early algebraic concepts. The ten teacher participants are from five state primary schools in middle class areas in Brisbane, Queensland. The findings from this investigation suggest that potentially many conflicts exist between the interest of a teaching experiment and that of professional learning. Some of these conflicts can be overcome, others can be minimised by restructuring, but some are fundamentally inherent when the methodologies are combined.

The new Queensland Year 1-10 Mathematics Syllabus (Queensland Studies Authority [QSA], 2004) offers an innovative approach to mathematics curriculum in Queensland. In particular, this syllabus reflects recent findings on effective pedagogy, appropriate mathematics content and sequencing of that content as reported by, for example the Institute of Educational Sciences (undated), Marks and Cresswell (2005), and McNeil (2006).

The changes introduced in the *Year 1–10 Mathematics Sylla*bus (QSA, 2004) have been sufficiently innovative that mathematics education research has received government support for projects to improve teachers' knowledge and classroom practices in the new areas. These projects have required the integration of professional learning (PL) programs and large scale teaching experiments (often based on the multi-tiered approach of Lesh and Kelly, 2000) in a manner similar to many international projects (e.g., Carpenter, 1996; Kaput & Blanton, 2001a; 2001b). The focus of the programs has been on identifying relationships between student learning and teacher knowledge that enable the development of innovative instruction and theories of learning (Cobb, 2000). Such relationships are usually found through the generation and testing of conjectures (Confrey & Lachance, 2000) and are at the "cutting edge" of knowledge building. Through them the link between research and practice can be made more acute, illuminating teacher PL. However, successful implementation of this methodology requires that the fundamental interests in conducting teaching experiments and PL be considered. Within this context of serving the interests of both, essential elements for success must be addressed.

Background

Elements of Successful Teaching Experiments

Teaching experiments were recognised during the 1970s as a way of bridging the gap between practice and research. As a result teaching experiments involve one or more teaching episodes where witnesses record details about the teaching, such that retrospective analysis of the teaching episode is possible (Steffe & Thompson, 2000). In addition, the researchers and the teachers work best when a relationship is formed that allows them to work as co-learners collaborating to further their own specific theory or understanding of what is happening within the classroom (Lesh & Kelly, 2000). The conjecture driven approach in the conduct of teaching experiments is often used with mathematics and this methodology requires that specific mathematics content be addressed and that innovative instructional sequencing of that pedagogy be paramount (Confrey & Lachance, 2000). These essential elements then allow for the conjecture to be revised and elaborated during the course of the research, "usually on the fly" (Steffe & Thompson, 2000, p. 277, citing Ackermann, 1995). It is in this way that the gap between theory and practice is bridged.

Elements of Successful PL

Theories on PL have developed over the last 40 years that take into account the complex nature of the relationship that exists between teachers and school environments that results in improved student outcomes (e.g., Blanton, Westbrook & Carter, 2005; Clarke & Hollingworth, 2002; Guskey, 2003; Lichtenstein, 2000; Riley, 2000; Sleegers, Bolhuis, & Geijsel, 2005; Stoll & Stobart, 2005). Despite the diversity of these theories, common essential elements of successful teacher PL have emerged.

One of these elements essential for PL success is that teachers must be involved in the identification of what they need to learn in the PL program to allow them to own this learning and the resulting teaching practices that emerge from it (Fullan, 2005). Teachers become more consciously committed to change if they have some ownership of their own learning, particularly when they are involved in a collegial environment where there is ongoing support (Clarke, 1994; Fullan, 1992; Hargreaves, 1994) which provides them with the opportunity to "reflect critically on their practices and fashion new knowledge and beliefs" (McLaughlin, 1997, p. 80). It is well documented in the literature that "... without companionship, help in reflecting on practice, and instruction of fresh teaching strategies, most people can make very few changes in their behaviour, however well-intended they are" (Joyce & Showers, 1995, p.6). However, despite efforts to encourage teachers to work collaboratively, research suggests that supportive environments are difficult to create and teachers continue to choose to work in isolation even if these so-called supportive environments are created (Lieberman, 1995; Little, 1999).

A second element is that successful PL takes time and requires teachers to have time to reflect, plan and trial ideas. A lack of time negatively affects

teachers' work practices and, consequently, educational change. Limited time allocated to PL and collegial planning often prevents teachers from seeing the benefits of their labour in terms of student outcomes (Heid et al., 2006). Without witnessing change in student outcomes, there is less incentive for teachers to change their beliefs and attitudes or their teaching practices. Moreover, the problem of time is not alleviated by delivery and implementation processes that are top down and where teachers are expected to merely co-operate and implement (Durrant & Holden, 2006).

Time problems are exacerbated by complexity. Hall (1995) looked at the apparent failure of teachers to implement multiple innovations simultaneously. He found that this type of professional pressure caused "...teacher burnout...over 50% of beginning teachers resigning within five years...teachers over worked and overloaded" (p.120). This is not an isolated finding; for example, Hargreaves and Evans (1997) found that the "effects on educational reforms on teachers in England and Wales in terms of reforms' substance, scope and speed of implementation have been devastatingly exhausting" (p. 2).

A third element essential for positive teacher change is to take into account the particular characteristics of the teachers and schools. For example, PL has been shown to be unsuccessful when it "does not acknowledge or address the personal identities and moral purposes of teachers, or the cultures and contexts in which they work" (Hargreaves, 1995, p. 14). As well, reforms that challenge teachers' beliefs about what constitutes "good education" may lead to resistance (Kelchtermans, 2005). These belief difficulties can be difficult to overcome if significant differences exist between the goals and cultures of teachers and PL leaders (Geiger & Goos, 2006; Richardson & Placier, 2001; Sealey, Robson, & Hutchins, 1997; Whitford & Metcalf-Turner, 1999).

Content Knowledge, PL and Teacher Change

The most significant element for successful change in mathematics is teachers' content knowledge (Ball, Lubienski & Mewborn, 2001). Inadequate content knowledge leads to ineffective teaching practices and inadequate student performance which removes motivation to proceed with reform. Yet, teachers with inadequate understanding of content have been found to focus on learning pedagogical skills at the expense of addressing their deeper mathematics content problems (Prichard Committee, 1995, cited by Hawley & Valli, 1999, p.142). Blanton et al. (2005) provide a theoretical basis to the issue of content knowledge by utilising Valsiner's (1997) extension of Vygotsky's (1978) theory on Zone of Proximal Development (ZPD). Vygotsky identified the ZPD to be the range within which a student's potential for learning occurs. He described this range as the difference between the level of tasks that can be solved with adult guidance (usually the teacher) and the level of tasks that can be independently solved. Valsiner (1997) extended the notion of ZPD to the relationship between PL leader (most commonly a researcher) and teacher. It is argued that insufficient content knowledge severely limits a teacher's ZPD reducing the level of novelty that the teacher can accommodate. This is supported by Hawley & Valli (1999) who argue

that "when content and learning tasks are novel or particularly complex, professional learning opportunities should incorporate well-rehearsed or familiar instructional strategies" (p. 136). Within this context, Blanton et al. (2005) examined teachers' responses to professional learning, and in particular the teaching and learning of algebra.

Traditionally, the teaching of patterns and algebra has been the domain of the secondary school in Queensland. However, one of the initiatives for the new mathematics syllabus was to extend patterns and algebra to the elementary (or, in Queensland, primary) school where most teachers are unfamiliar with its content and unsure whether it is suitable for elementary grades. When teacher content knowledge is inadequate and teachers do not believe that the topic should be taught in the primary school, teaching can be ineffective unless content is upgraded and beliefs addressed (Ball et al., 2001; Darling-Hammond & McLaughlin, 1995). This suggests that Queensland primary teachers will have difficulty implementing the new patterns and algebra syllabus and experience severely limited ZPD in relation to professional learning in patterns and algebra. Research has found that Queensland primary teachers lack confidence in their mathematics-teaching abilities (Nisbet, 2005) and this lack is related to poor content knowledge (Lamb, 2003).

Focus of this Paper

To help address primary teachers' content and pedagogy limitations with patterns and algebra, the Queensland Department of Education Training and the Arts provided funds and school sites to support the last four years of a longitudinal project to study: (1) Years 2 to 6 primary school students' development of early algebraic thinking through a series of teaching experiments; and (2) primary teachers' professional learning of patterns and algebra content and pedagogy through classroom trials of instruction developed for the teaching experiments.

The effectiveness of the PL of teachers in the fourth year of this five year longitudinal research project is discussed in this paper. In particular, the interaction between teachers and researchers are discussed highlighting the conflicts that arose between the provision of PL and teaching experiments. This discussion seeks to answer two research questions: (1) what conflicts exist between teachers and researchers during the conduct of a teaching experiment that incorporate PL, and (2) how can these conflicts be minimised.

Design of the Project

The methodology adopted for the early algebraic thinking project and the PL study described in this paper was qualitative and longitudinal, comprising three sets of teaching experiments and three PL episodes over the course of each of 5 years. The teaching experiments utilised the "conjecture driven approach" of Confrey and Lachance (2000, p. 231) to investigate Years 2 to 6 primary students' cognitive development with respect to patterns and algebra. The PL episodes

focused on providing teachers with resources and support to successfully trial patterns and algebra activities in their classrooms. The focus of data gathering in the PL episodes was teachers' changed knowledge and classroom practices with respect to patterns and algebra, and the cause of these changes.

Participants

The participants in the PL study were students in ten Year 5 classes and their teachers from five primary schools. These schools had been selected several years earlier due to an interest expressed by the principals in becoming involved in research that linked their schools to a university. However, due to the longitudinal nature of the project, the teachers were new to the project but most of the students and four of the five principals had been involved in the project for 2 to 3 years. Four of the teachers had taught for less than 2 years; the other six had taught for more than 5 years. The teachers had been told of their participation at the beginning of the school year.

The 5 schools were middle class state primary schools from inner city suburbs in Brisbane, Australia. They had each received "Excellence in Schools" awards for innovative programs in a range of fields including mathematics, science and technology. Consequently, their involvement in other projects with the demands this places in developing and implementing innovative pedagogy had kept the teaching staff at the forefront of educational change.

Phases in the Project

There were three phases of teaching experiments, each focusing on a different aspect of the Patterns and Algebra Strand in the mathematics syllabus. The first phase comprised teaching experiments on growing patterns[1] where the researchers compared the use of tables with no tables in finding position rules[2] by allowing one class to use tables and not allowing their use in the other class. The second phase comprised teaching experiments on change and functions where students worked with function machines[3] and were introduced to solving for unknowns by backtracking.[4] The third phase comprised teaching

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[1] Growing Patterns have discernable units commonly called terms and each term in the pattern depends on the previous term and its position in the pattern.

[2] When analysing growing patterns it is important to understand the relationship between the position and the number of elements in that position. This reasoning leads to the position rule allowing for the calculation of the number of elements in any position.

[3] A Function Machine is the common way to introduce change. The function machine is a box, which changes objects or numbers. The function machine can have the rule on it, e.g. x 2 + 3 or "if red then green", then numbers on cards or coloured objects — children put a card/object in the IN part and it is changed and a new card/object comes out the OUT part, e.g. Card IN 4, card OUT 4 x 2 + 3 = 11. It is recommended that there is one set of cards or objects for the children and another set inside the box for changing.

[4] If change is 1:1 then this can be backtracked or reversed. Change based on the four operations can be backtracked (squares and cubes cannot be reversed); for example + 2 can be backtracked

experiments on equivalence and equations and again compared two different teaching materials; one class modelled equations by comparing masses with a beam balance to solve for unknowns, while the other class modelled equations by comparing lengths to solve for unknowns.

Each of the phases involved two sets of teaching experiments, one set taught by the researchers and the second taught by the teachers themselves. In addition two half-day PL sessions, one prior to, and one following, the researcher-taught teaching experiments occurred at each phase. The extended nature of each phase was designed to specifically address the concerns listed in the literature in relation to time so that teachers would have the time to plan, trial and reflect. In addition these sessions also recognised the importance placed on the role of developing a collegial environment which would lead to the teachers developing a sense of ownership while at the same time allow them to become co-learners with the researchers. The two half day PL sessions also gave the teachers considerable time to embrace the new content and pedagogy in the patterns and algebra strand they now had to teach. The components and sequence of each phase were as follows.

First PL session. The first session was used to introduce the topic and to describe the content and pedagogy underlying the topic.

Researcher-taught teaching experiments. The first experiments were composed of four one-hour lessons and were undertaken in two selected classrooms (chosen so that as many classrooms and schools as possible were involved in each year). They were used to trial and modify teaching ideas for the selected topic and were constructed by the researchers for Year 5 students.

Second PL session. The second session was on the actual lesson plans and research findings from the teaching experiment; the lessons plans were promoted as instruction that had been trialled, modified and were now ready to implement. The researchers were committed to openly discussing all aspects of the teaching experiment to promote research dialogue between themselves and the teachers. They showed video segments of the teaching episodes and samples of students' work. Time during the sessions was allocated to the teachers from the classes in which the teaching experiments had been undertaken to discuss, from a participant observer's view, how the lessons proceeded and where improvements might be possible. It was during these discussions that input from the other participating teachers was sought. It was believed that these discussions would assist the teachers to co-construct the content and pedagogy as delineated in the lessons.

Teacher-taught teaching experiments. The second experiments were to allow teachers to trial the lessons in their own classrooms. These teacher trialled

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by – 2 and x 7 by ÷ 7. Such reversals can be applied to sequences of operations. However, it is important to reverse the order of the operations as well as to reverse each operation. When backtracking a change, the order of the numbers stays the same when using an arrow diagram: Change: $5 \xrightarrow{+6} 11$ Reverse: $5 \xleftarrow{-6} 11$ but when using an equation, the order of the numbers also reverses. Change: $5 + 6 = 11$ Reverse: $11 - 6 = 5$ When reversing a sequence of operations the order of the operations as well as the operations are reversed. For example, + 2, x 3, – 5 is reversed as + 5, ÷ 3, – 2.

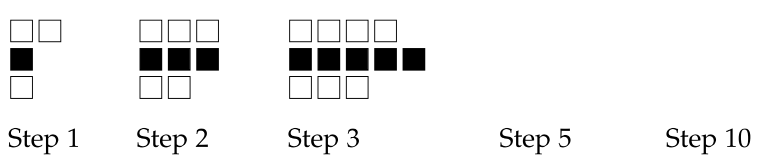
lessons were a necessary component of the project as the cohort of students had participated in this study for the previous three years and it was planned for the project to continue for a further year. Therefore it was important to ensure that the teachers implemented the lessons with their students following the second PL seminar to ensure all students had continued to construct their understanding of patterns and algebra in preparation for the teaching in the final year of the project. To provide support for these experiments, an experienced teacher, working as a research assistant, was available to attend all lessons, support the teachers, and provide the materials that were used by the researchers in their lessons.

Instruments

Multiple sources of data were collected on the PL part of the project over the course of the academic year. These sources, described below, included teacher interviews, teacher surveys, and observations of teachers' participation in PL sessions and teacher-taught teaching experiments.

Teacher interviews. The teachers were interviewed at the commencement and completion of the academic year. The first interview was designed to gather baseline data on what the teachers' identified as necessary for learning about the teaching of algebra in the elementary school. Part of this interview involved the teachers examining a patterning problem that their students had completed while in Year 4. They were asked to anticipate problems that they might encounter when teaching such a pattern (see Figure 1). The problem requires the completion of a growing pattern and identification of the position rule.

At the completion of the year the teachers were again interviewed. This interview reflected on teachers' beliefs and attitudes about the teaching and



a) Complete the missing steps.

b) How many ■ in the 18th step?

c) Which step has 39 □ ?

d) Which step has 39 ■ ?

e) Write the position rule for this pattern.

f) How would you calculate the number of tiles in the nth step?

Figure 1. Pattern problem shown to teachers at initial interview.

learning of early algebra in the primary school and their perceptions of the PL provided through the project.

Teacher survey. At the initial interview the teachers were given a survey of items covering demographic information, professional learning preferences, and their beliefs and attitudes about teaching mathematics. Examples of items were: *What do you think is the best way to teach mathematics with your current class?* and *What would be the greatest help to you in improving your students' mathematical performance*?

Observations. The observations of the teachers at the PL sessions gave an indication of their knowledge and beliefs about algebra teaching and learning. A research assistant recorded these points during the PL sessions. The observations of the teachers while teaching the lessons gave further insights into their content and pedagogy knowledge of this new strand in the syllabus. The research assistant also recorded these observations. The PL sessions and the teacher delivered lessons were not video recorded by request of the teachers. The researcher led lessons were video recorded while three observers took field notes.

Results

The data gathered were analysed for different phases of the project: (a) the interview and survey conducted at the commencement of the project, (b) the teaching experiments and professional learning seminars and (c) and the interview conducted at the conclusion of the project.

Teacher Interview at the Commencement of the Project

Nine of the 10 teachers were interviewed at the beginning of the year. The interview focused on algebra teaching and the pattern problem (see Figure 1). One teacher, with less than 2 years experience, chose not to be interviewed. He gave as a reason his involvement in another project.

Algebra teaching. Eight of the nine teachers interviewed expressed concern about their ability to teach early algebra. They all gave the same reasons; they had no teaching experience in the topic and their own high school experience with algebra did not give them the confidence to teach it in the primary school. They also expressed concern about their own content knowledge and as such were apprehensive about what would be expected of them during the project. For example, one teacher said:

> I don't have a clue how to do that problem. If I think about it a while I might be able to get it ... Can I take it away and do it later? ... This sort of thing is a bit too tricky. I haven't done this sort of thing for years.

The only teacher who was not concerned about the content or pedagogic demands of the patterns and algebra strand in the new syllabus had completed a Master of Education (Mathematics) several years earlier.

Pattern problem. When asked to examine the problem and discuss aspects that might be difficult for their students, and the reasons for the anticipated

difficulty, all teachers immediately began completing the question and for most, difficulties were encountered from the outset. The teachers' discussion then centred on their own difficulties with the pattern problem with most saying they did not know how to solve the problem. Table 1 details the teachers' correct responses.

Table 1
Nine Teachers' Correct Responses to Pattern Problem

Question	5th Term	10th Term	Number of ■ in step 18	Step with 39 □	Step with 39 ■	Position Rule	No. of tiles in nth step
Number of Correct Responses	5	2	1	1	–	2	1

These results highlight the limited content knowledge on patterns of this group of teachers.

Teacher Survey at the Commencement of the Project

The survey of demographic information, professional learning preferences and beliefs and attitudes about the teaching of mathematics was given to all nine teachers at their initial interview. The teachers were asked to bring the completed forms to their first seminar. Only two teachers completed and returned their surveys. The remaining teachers were given another copy of the survey with a postage-paid envelope and followed up with emails and phone calls, only two more surveys were returned.

Demographic information. Of the four returned surveys, two were in their first year of teaching and they gave no indication as to their professional learning format preferences or their beliefs about how children learn mathematics. The two other completed surveys were by experienced teachers and they too failed to express their beliefs about the teaching of mathematics. However, all four teachers wanted the professional learning to take place during the school day with one insisting that it not interfere with the school sport afternoon.

None of the four teachers had used a website to support their preparation of their mathematics lessons, although a first year teacher wrote the internet was her main source of information for keeping up to date and for preparation of lessons. The other three teachers used a range of student workbooks as their main source of information regarding what was to be taught and how to teach it. Professional learning in mathematics did not feature highly on these four teachers' surveys. None of them had been to a mathematics professional learning session provided by a person outside their school staff. However, only one of the three teachers thought they needed professional learning in mathematics education. The four teachers were all aware that the new Queensland Years 1–10

mathematics syllabus (QSA, 2004) would be mandated in 2007. None of the four demonstrated a concern about their content or pedagogy knowledge even though all four had attempted the pattern problem (Figure 1) and encountered difficulty.

The Teaching Experiments and PL Seminars

As stated before, the plan was for the project to comprise teaching experiments and PL sesminars in three topics: patterns, change and functions, and equations and equivalence. In the first topic, a teaching sequence for growing patterns using tables was compared to a teaching sequence in which tables were not allowed. The purpose was to investigate the students' ability to identify the position rule for a growing pattern composed of tiles (as in Figure 1) with and without tables. In the second topic, functions were investigated using "function machines" to identify the change rules involving multiplication and division and to introduce "backtracking." Backtracking represents the inverse relationship to the function, which can be used to identify unknowns by reversing the function. These functions were related to real world problems. In the third topic, instructional programs using mass and length were trialled and compared as an alternative representation for solving for unknowns in equivalence problems using the balance rule.

Due to difficulties with finding a common time for all teachers, the initial PL session for the first phase was not held. In previous years, the conduct of the project along with its aims were described in this session, the content and pedagogy underlying the topic of the first phase, patterns, were also provided. As this session could not be held, this material was discussed at the scheduled second PL seminar following the experimental lessons. However, the missing PL session meant that the two teachers whose classrooms were being used by the researchers for their teaching-experiment lessons had not been instructed on what the researchers were doing and what their role as a participant observer involved. As a result, they became agitated with what the researchers were doing and unrest grew between them and the researchers, which affected the program across the year.

Furthermore, two first year teachers left their schools just before the teaching experiments in the second phase. This reduced the number of classrooms in the project for this year from 10 to 8.

Teacher involvement. The three teaching experiments undertaken by the researchers remained effective in developing, trialling and comparing innovative instructional sequences, satisfying the researchers' desire to develop and test conjectures. Each of the three phases involved two of the ten teachers as observers. However, the teaching undertaken by the remaining eight teachers for each phase became problematic. The teachers did not show interest in trialling the lessons in their own classrooms.

This was first evident in the use made of the teacher/research assistant who was employed by the project to support the teachers in delivering their lessons. During the first topic, only two teachers accepted the offer of support. An

experienced teacher asked for support with all lessons; the second teacher, a first year teacher and from the same school, only wanted assistance during the first two lessons in the series of four one-hour lessons. The remaining six teachers each said that they felt confident to give the lessons themselves and would do so at a time convenient to them. For the second topic, two different teachers accepted the support. They each decided that they did not want support beyond the first lesson. By the third topic, only one of the teachers asked for the support of the experienced teacher in trialling the developed lessons. All four of her lessons were supported. The support offered during these lessons included the provision of all materials needed to conduct the lesson. The supporting teacher did not become involved in the lessons unless directly requested by the teachers and in each instance this was only in the form of a question involving use of terminology.

The general findings from these lessons, as noted by the teacher/research assistant, were that each of the teachers adhered closely to the provided lesson plans while allocating extended time during the lesson for student manipulation of resources. However each promoted only limited discussion with students on their use of the resources. The teachers preferred instead to ask low order questions requiring one word answers.

Unrest between researchers and teachers. For the first phase, the researchers compared the effectiveness of tables with no tables in finding position rules for growing patterns. The two classes were from the same school. Each class received different instructions on how to identify missing terms in a pattern and then the position rule for the growing pattern that had been made using coloured tiles (similar to Figure 1). The first class used tables and the second did not.

The agitation of the teachers, due to the cancellation of the initial PL session to inform them of how the teaching experiments would be undertaken, was exacerbated by differences that emerged between the two classes. The first class (using tables) appeared to achieve at a much higher rate than the second (not using tables) where there was difficulty maintaining student engagement. This caused some misgivings by the teacher of the second class because he "knew" how much better the other class was achieving and did not understand why his class was not receiving the other class's instruction. Even though, on the post-tests, no advantage was evident, the teacher whose class did not have access to the tables became disillusioned with the teaching experiment aspect of the project and subsequently became a negative force at the following professional learning session.

Fortunately, the teaching experiments for the second topic proceeded well with both classes receiving similar instruction on functions. Almost all teachers who attended this professional learning session developed a greater collegial spirit, which contributed to the discussions.

The third topic was also well received by the teachers. This topic focused on equations and equivalence utilising two separate pedagogical approaches. However in response to the difficulties encountered earlier in the year, two different schools were chosen for the experimental lessons. By the third topic, the

initially disillusioned teacher had become very positive about the concepts studied and how easily his students were able to apply them to different contexts. He explained at the final professional learning session how his students' ability to problem solve in mathematics had developed over the course of the year. He appeared to become one of the loudest advocates for the strengths of the project. However, this may not have given a true indication of his feeling about the project as he was unwilling to be interviewed at the conclusion of the project.

Teacher Interview at the Conclusion of the Project

At the completion of the academic year, only five of the original ten teachers were available to be interviewed. Two first year teachers had left their schools and the teacher who was unable to be interviewed at the commencement of the year was again unavailable. The two teachers who had been involved in the first teaching-experiment topic also chose not to be interviewed.

All five teachers who were interviewed were positive about the project. They expressed the belief that the teaching of patterns and algebra was important in the primary school and that their involvement with the project had helped them professionally. One teacher found her involvement in the project so rewarding that she asked to be involved again in the following year. However four of the five teachers said they did not appreciate the depth of discussion on the experimental nature of the lesson plans. They wanted to be told what the outcome was and how they should teach their students. Essentially, they wanted 'hands on' tasks that they could do with the children, that they knew were useful and developed the concept being taught. The research side of the project was not of particular interest to them. They simply wanted to know how to teach this new strand in the syllabus.

However, it became evident in the final interviews that many of the teachers were not undertaking the lessons that had been developed from the researchers' teaching experiments. Each of the five teachers interviewed expressed their inability to find time to conduct all the experimental lessons. They believed that it was something they needed to do when they had spare time as other more pressing demands were being made upon their time. However, they each articulated that they had the lesson plans, knew how to make the necessary materials and felt sufficiently confident to conduct the lessons when the time availed.

Discussion

Two factors influenced in many ways the success of the study; teacher content knowledge and time. These factors heightened the conflict experienced between the researchers and teachers in terms of their goals for the project; in fact, between the teaching experiments and the provision of professional learning. Consequently the completion of the teacher-taught teaching experiments that followed the professional learning were not very successful while in contrast, the researcher taught teaching experiments were very successful.

Findings and Conflicts

Findings in terms of these conflicts are now discussed along with implications for how these conflicts may be minimised.

Teacher mathematical knowledge. The teachers' content knowledge was limited in the area of patterns and algebra as demonstrated by their responses to the first interview (See Figure 1), supporting the findings in the literature (Ball et al., 2001; Ma, 1999). The teachers did not have the content knowledge to complete the patterning question that their students had worked on the year before. The researchers did see this as an impediment to teacher growth and considerable time was taken to explain the content and pedagogy to the teachers in later PL sessions. However, discussions at the PL sessions and lesson observations indicated that the teachers clearly needed more time to support their learning as it was obvious they did not fully understand the mathematics of this new topic in the Queensland mathematics syllabus (Blanton, 2005; Pritchard Committee, cited in Hawley & Valli, 1999). Furthermore they were reluctant to move beyond the script as detailed in the lesson plans (Valsiner, 1997).

Theory versus practice. This study supports previous research by demonstrating the gap between theory and practice in research (Joyce & Showers, 1995). The researchers' first concern was to develop effective teaching practices that were "cutting edge", exploring every avenue available to them to maximise teacher actions to bring about student learning in early algebraic concepts (Confrey & Lachance, 2000). This is in direct contrast to what the teachers sought from the project. The teachers were generally not interested in the research aspects of the development and implementation of the experimental lessons offered by the researchers.

Furthermore, the teachers were not interested in the academic debate about why a strategy worked or didn't work or how it may be extended or changed to induce improved outcomes, whereas these aspects were of particular interest to the researchers (Geiger & Goos, 2006; Richardson, 1994). The teachers' interest did not extend beyond that of practical application. Their fundamental concern was how they were to address their day-to-day concerns of conducting a lesson on patterns and algebra. This conflict supports the findings in the research literature that the teachers wanted to focus on learning pedagogical skills at the expense of strengthening their mathematical understanding (e.g., Heid et al., 2006; Prichard Committee, cited in Hawley & Valli, 1999, p.142). This was particularly evident as the teachers struggled with the new content. Consequently the teachers did not develop a sense of themselves as co-learners — a positive outcome from teaching experiments identified by Lesh and Kelly (2000).

Ownership of the project. Due to the teachers limited content knowledge for patterns and algebra the interactions between researchers and teachers appeared to conflict quite significantly with the objective of ownership listed in the literature as essential for successful professional learning (Clarke, 1994; Fullan, 2005; Hargreaves, 1995) in as much as the interactions clearly presented the lessons as being owned by the researchers. Thus, it was difficult for the teachers

to feel that they had ownership of the project, including the developed lessons. They had not chosen to be part of the project; their principals had simply informed them of their participation at the beginning of the year. In addition, nine of the ten teachers had identified that they had limited knowledge in early algebra but they did not have sufficient knowledge to identify what they believed they needed to learn and how they would learn it (Fullan, 2005). They were prepared to accept whatever was presented to them. As a result, the researchers prepared the lessons, trialled them and then presented them for the teachers to use, albeit with some discussion, at the second PL session for each topic. The teachers' role was restricted to trialling the lessons in their own classrooms and suggesting modifications.

The teachers' limited content knowledge also impacted on the PL sessions. The PL component of the project functioned "top down" with the researchers directly focusing on training in the delivery and implementation of the set lesson plans. This prevented teacher ownership and made the PL sessions not as effective as they could have been (Durrant & Holden, 2006), although the sessions were very useful as a way to have experimental lessons tested. The teachers' limited prior experience with algebra, and reluctance to conduct the experimental lessons only further reduced ownership and prevented active participation in the PL sessions.

Compounding the difficulty of lack of ownership was the constraint of time. The teachers were all involved in other projects and were implementing a range of new policies and syllabuses adding to the complexity of their work. These pressures on teachers cause stress, burn-out and resistance (Hall, 1995; Hargraves & Evans, 1997). Furthermore, time was not set aside for discussion of the lessons after the teachers implemented them. In the PL sessions that followed the teachers' teaching experiments, the topic of the next phase was discussed. The result was that the teachers, in this next PL session, did not ask any questions of the previous set of lessons, discuss any interactions they had had with their students or highlight any concerns. In hindsight, allocation of time to the PL session at the commencement of the next phase for discussion of the previous lessons would have been beneficial. This may have increased the teachers' contribution to the developed lessons, increasing their ownership, along with their interactions with the researchers (Fullan, 2005; Heid et al., 2006; McLaughlan, 1997). More time available could also have provided opportunities for greater trust between the researchers and the teachers to develop (Sealey, Robson, & Hutchins, 1997; Whitford & Metcalf-Turner, 1999).

In summary, time became the issue for teachers' lack of ownership of the project and its lessons because of the need for the researchers to move onto their next trial (which was in a different phase with a different topic). Adherence to the schedule for the teaching experiments did not coincide with the development of a sense of ownership for the teachers. Because of the researchers' need to trial and compare teaching approaches, this conflict proved difficult to resolve.

Interest and motivation. Conflict between researchers' and teachers' interests and motivations was evident in the project. The researchers wanted to trial the

most innovative ideas to see if they would work; the teachers were interested in something practical that they could use and understand. The researchers maintained their interest and motivation by being heavily involved in inventing and planning the lessons and discussing the findings with each other prior to the PL sessions; the teachers lost interest and motivation because of the lack of time for collegial planning, reflection and feedback before, during and after the PL sessions. All these aspects prevented the formation of a learning community (Fullan, 1992). Motivations for the project were different and the teachers did not have control over the conduct of the PL sessions.

There were aspects of the PL sessions that did reflect good practice. For example, modelling of the lessons in actual classrooms has been identified as an important action (Clarke, 1994) and this was addressed by the project. The researchers modelled the lessons in two of the classrooms during each phase and showed video recordings of these lessons at the PL sessions. However, the teachers' interests in the modelling appeared to be limited to familiarisation of the presented material; there was little modification of lessons.

There were also inadequate aspects of the PL sessions. Few teachers completed the survey at the start of the year and there was virtually no feedback on preferred PL approaches and activities. Therefore, all the planning came from the researchers and the teachers appeared content to listen. The researchers would have been open to suggestion had the teachers offered suggestions, however, they remained passive recipients.

Follow-up and sharing. There was little follow up of the teacher-taught teaching experiments and little sharing of ideas and experiences between teachers, a consequence of the researchers' focus on the next activity and the teachers' reluctance or inability to provide feedback. It is not known precisely how many of the lessons teachers gave to their students. The researcher taught lessons or those attended by the teacher/research assistant are the only lessons that can be confidently said to have been conducted. Without follow-up and sharing with other teachers, there was no encouragement for the teachers to give the lessons.

The result of not giving the lessons was that the teachers only witnessed limited growth in their students' understanding of early algebra and so may not have received the positive feedback from students essential to maintain a strong PL involvement (Clarke & Hollingsworth, 2002). Although they expressed the belief at the final interview that the teaching of patterns and algebra was important in the primary school, none of the teachers had conducted the full set of lessons.

Forming and testing conjectures. The teaching experiments were based on forming and testing conjectures, and this was problematic. A conflict of interest developed between the researchers and the teachers in the first phase when two experiments were used to form and test conjectures, a fundamental component of the conjecture driven approach to teaching experiments (Guskey, 2003). This reduced the opportunities for researcher and teacher to develop a sense of mutual respect (Fullan, 1992).

Two classes, side by side in the same school, were given different treatments. It initially appeared that one class was advantaged. The teacher who felt his class was disadvantaged complained that it was a waste of his and his students' time to be involved in such experiments. Even when the students were post-tested and no disadvantage was apparent, he did not immediately change his attitude toward the project (see Kelchtermans, 2005, for a similar situation). This experiment gave the researchers valuable data (see Warren, 2005) and also provided the teachers with alternative pedagogy strategies for the teaching of patterns. However it created a wedge between researchers and this particular teacher participant, which did impact on the PL session. This conflict was prevented in the third teaching experiment by changing the structure; using two different schools for the different treatments.

Working in isolation. The teachers chose to work mainly in isolation. They did not value the opportunity to have another teacher present for support and feedback. The literature argues that developing a collegial dialogue that goes inside the classroom is difficult to achieve (Lieberman, 1995; Little, 1999). This was evidenced in this project. Because of the need to maintain innovation in teaching, the lessons were at the limit, or beyond the limit, of teachers' understanding within the limited PL of the project. In this situation, the teachers felt unsure of the teaching and did not want others present. Thus, their work in isolation was difficult, and proved impossible, to eliminate.

Summary and Recommendations

In summary, there was conflict between the priorities and interests of the researchers and the teachers that was inherent within the methodology.. Moreover, these conflicts, resulting from the combination of teaching experiments and PL, were heightened by the issue of time and the teachers' limited knowledge of the new content in the primary syllabus, patterns and algebra.

The schools participating in this project were initially chosen because of motivated and enthusiastic principals. Their interest in remaining at the forefront of educational innovation led them to participate in a range of research projects and departmental innovations, impacting significantly on the teachers in this particular year of the longitudinal study. A commitment from the principals regarding the demands placed on their teachers is recommended. This will not fully address the issue of time but it will go some way to alleviating the range of demands placed on teachers outside their usual teaching responsibilities.

The context of this project was mathematical content and pedagogy that was new to the teachers. Consequently the teachers' interest in this project and in particular the PL sessions was to gain sufficient content and pedagogic skills to conduct the necessary lessons. This conflicted with the interests of the researchers, as they wanted to operate at the "cutting edge" of knowledge building. In projects such as this where new content and pedagogy is the context, it is recommended that this conflict can best be reduced by significant investment in time and teaching of the new content. This will allow the teachers to construct

the necessary content knowledge prior to the commencement of the teaching experiment. By adding this phase the teachers will then be in a position of enhanced knowledge and more open and responsive to the researchers thereby reducing the gap between theory and practice. It is acknowledged, however, that the interests of the teachers and the researchers are intrinsically different and it is therefore important for the researchers to remain diligent with teacher support while satisfying their own research interests.

Conclusion

Each of the aspects listed in the discussion, summary and recommendation sections of this paper had a profound impact on the project and, in particular, in convincing teachers of the personal benefits arising from their participation in this project. This was initially seen in the limited response to the completion of the questionnaires and the refusal by one teacher to participate in anything other than at a superficial level. In conjunction with the teachers' lack of conviction about the benefits of the project, time pressures contributed to the teachers' failure to implement the lessons. This directly impacted on the teachers' contribution to the professional learning sessions and to the limited success of the learning community.

There are many aspects of conflict that can be identified when combining "cutting edge" teaching experiments with professional learning seminars. Some of these can be overcome and others ameliorated by being diligent with communication, providing extra support and some restructuring. However, some are intrinsic to the nature of each process.

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